

Particles

17 questions · 70 marks

Answer all questions. The marks available are shown against each part. Every question is taken unaltered from a past paper; the source is noted beneath it. In Section A, choose the best answer and write its letter in the box.

Section A · Multiple choice

10 questions · 10 marks

1. The Σ^0 baryon, composed of the quark combination uds, is produced through the strong interaction between a π^+ meson and a neutron. 1 mark

$$\pi^+ + n \rightarrow \Sigma^0 + X$$

What is the quark composition of X?

[1 mark]

- A** $u\bar{s}$
B ud
C $u\bar{d}$
D $ud\bar{s}$

☐
☐
☐
☐

Answer

2. The gravitational force is one of the four fundamental forces.
The ticks in the table match particles with the other fundamental forces.
- In which row is the particle matched to the only other fundamental forces it experiences? **[1 mark]**

	Particle	Electromagnetic force	Weak nuclear force	Strong nuclear force	
A	μ^+	✓	✓		☐
B	$\bar{p}$	✓		✓	☐
C	π^0	✓	✓	✓	☐
D	ν_e		✓	✓	☐

Answer

— AQA 7408/1 Physics · 2021 · Paper 1, Question 9

3. Which statement about muons is correct? **[1 mark]** 1 mark

- A They consist of a quark and an antiquark. ☐
- B They include pions and kaons. ☐
- C They are subject to the strong interaction. ☐
- D They decay into electrons. ☐

Answer

— AQA 7408/1 Physics · May 2023 · Paper 1, Question 10

4. The quark combination of a particle is $s\bar{u}$. 1 mark
- Which is true for this particle? **[1 mark]**

- A It has a baryon number of 1 ☐
- B It has a charge of $-1.6 \times 10^{-19} \text{ C}$. ☐
- C It is a pion. ☐
- D It has a strangeness of $-\frac{1}{3}$ ☐

Answer

— AQA 7408/1 Physics · 2021 · Paper 1, Question 12

5. A nucleus contains N neutrons and Z protons.

1 mark

Which combination of N and Z gives a nucleus with the greatest specific charge?

[1 mark]

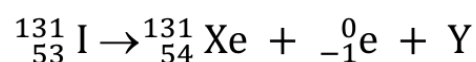
	N	Z	
A	6	5	☐
B	8	7	☐
C	16	13	☐
D	20	17	☐

Answer

— AQA 7408/1 Physics · May 2023 · Paper 1, Question 9

6. An iodine nucleus decays into a nucleus of Xe-131, a beta-minus particle and particle Y.

1 mark



Which is a property of particle Y?

[1 mark]

- A** It has a lepton number of +1
- B** It is an antiparticle
- C** It is negatively charged
- D** It experiences the strong interaction

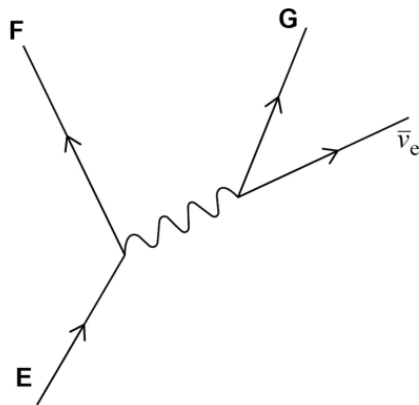
☐
☐
☐
☐

Answer

— AQA 7408/1 Physics · June 2018 · Paper 1, Question 12

7. The diagram represents a quark change in which an electron antineutrino is produced.

1 mark



What are **E**, **F** and **G**?

[1 mark]

	E	F	G	
A	up quark	down quark	β^-	☐
B	down quark	up quark	β^-	☐
C	up quark	down quark	β^+	☐
D	down quark	up quark	β^+	☐

Answer

— AQA 7408/1 Physics · May 2023 · Paper 1, Question 11

8. Two gamma photons are produced when a muon and an antimuon annihilate each other.

1 mark

What is the minimum frequency of the gamma radiation that could be produced?

[1 mark]

- A** 2.55×10^{16} Hz ☐
- B** 5.10×10^{16} Hz ☐
- C** 2.55×10^{22} Hz ☐
- D** 5.10×10^{22} Hz ☐

Answer

— AQA 7408/1 Physics · June 2018 · Paper 1, Question 10

9.

Fluoride ions are produced by the addition of a single electron to an atom of fluorine ${}^{19}_9\text{F}$.
What is the magnitude of specific charge of the fluoride ion?

1 mark

[1 mark]

- A

$3.2 \times 10^{-26} \text{ C kg}^{-1}$

☐
- B

$8.4 \times 10^{-21} \text{ C kg}^{-1}$

☐
- C

$5.0 \times 10^6 \text{ C kg}^{-1}$

☐
- D

$4.5 \times 10^7 \text{ C kg}^{-1}$

☐

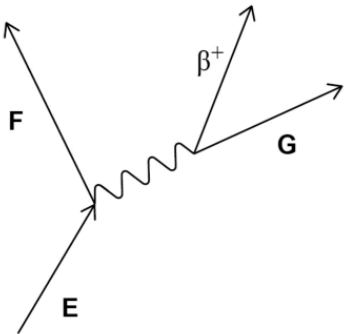
Answer

AQA 7408/1 Physics · June 2018 · Paper 1, Question 9

10.

The diagram represents a particle interaction.

1 mark



Which row identifies particles **E**, **F** and **G**?

[1 mark]

	E	F	G	
A	up quark	down quark	neutrino	☐
B	down quark	up quark	neutrino	☐
C	up quark	down quark	antineutrino	☐
D	down quark	up quark	antineutrino	☐

Answer

AQA 7408/1 Physics · 2021 · Paper 1, Question 11

Section B · Structured questions

7 questions · 60 marks

11. The neutral lambda particle Λ^0 is a baryon with a strangeness of -1 6 marks

One possible decay for a Λ^0 is

$$\Lambda^0 \rightarrow \pi^0 + n$$

1

Deduce the quark structure of a Λ^0 .

[1 mark]

2

State and explain which interaction is involved in this decay.

[2 marks]

3

An antiparticle of the neutral lambda particle decays into a neutral pion and particle **X**.

Identify **X**.

[1 mark]

4

The rest energy of a Λ^0 is equal to the energy of a photon with a frequency of 2.69×10^{23} Hz.

Determine, in MeV, the rest energy of a Λ^0 .

[1 mark]

rest energy =

MeV

5

The discovery of particles such as the Λ^0 is made by large international research teams.

Suggest **one** reason for this.

[1 mark]

— AQA 7408/1 Physics · May 2023 · Paper 1, Question 1

12.

1

Two isotopes of iodine are $^{125}_{53}\text{I}$ and $^{131}_{53}\text{I}$.

7 marks

Determine, for these two isotopes, the difference between the constituents of the nuclei.

[1 mark]

0 1 . 2

A $^{131}_{53}\text{I}$ nuclide undergoes beta (β^-) decay to form a xenon nuclide.

State the nucleon number of the xenon nuclide.

[1 mark]

0 1 . 3

A $^{125}_{53}\text{I}$ nuclide decays by electron capture to form a tellurium nuclide.

State **two** differences between the constituents of the iodine nucleus and the tellurium nucleus it decays into.

[2 marks]

[3 marks]

1

2

3

[illegible]

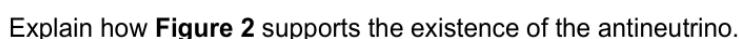
13.

7 marks

1

[1 mark]

Figure 2



The existence of the antineutrino was confirmed by experiments in which antineutrinos interact with protons. The equation for this interaction is:



Identify particle **X**.

4

The positron released in this interaction is annihilated when it encounters an electron. A pair of gamma photons is then produced. Particle **X** can be absorbed by a nucleus. This produces another gamma ray. **Table 1** contains data for three gamma photons detected during an antineutrino–proton interaction experiment.

Gamma photon	Photon energy / J
G1	5.0×10^{-14}
G2	6.6×10^{-14}
G3	1.0×10^{-13}

Deduce which of the three gamma photons could have been produced by positron annihilation.

— AQA 7408/1 Physics · 2022 · Paper 1, Question 2

14. 1 State the names of the four fundamental interactions. 7 marks
[1 mark]

- 1
- 2
- 3
- 4

2 State the products of the decay of a free neutron. **[1 mark]**

3 Explain which of the fundamental interactions is responsible for the decay of the neutron. **[2 marks]**

4 The forces between two moving electrons cause their paths to change.
 Explain, using the concept of exchange particles, why the electron paths change. **[3 marks]**

— AQA 7408/1 Physics · May 2024 · Paper 1, Question 1

15.

A positive pion collides with a neutron and the following interaction is observed:

9 marks

$$\pi^+ + n \rightarrow K^+ + \Sigma^0$$

Σ^0 is a neutral sigma particle with a strangeness of -1

The interaction can be used to deduce the classifications of the Σ^0 .

- 1
- Identify the classifications of each particle in **Table 1**.
Tick (✓) the appropriate boxes for each particle.
- [2 marks]

Table 1

Particle	Baryon	Hadron	Lepton	Meson
π^+				
n				
K^+				
Σ^0				

- 2
- A conservation rule predicts that the following interaction **cannot** occur:
- $$\pi^- + n \rightarrow K^- + \Sigma^0$$
- State the conservation rule.
Go on to explain your answer.
- [3 marks]

One way in which neutral pions decay is

$$\pi^0 \rightarrow e^- + e^+ + \gamma$$

- 3
- Compare the rest energies of the particles involved in this decay.
- [2 marks]

- 4
- The decay of the neutral pion leads to the production of further gamma photons.
Explain why.
- [1 mark]

5

The Standard Model is a theory that classifies elementary particles. Evidence for the theory has been collected since about 1950. However, the term Standard Model has only been used since 1973.

Suggest why progress in particle physics is slow.

[1 mark]

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16.

Cosmic rays are high-energy particles that come from space. Most of these particles are protons. There are other particles in cosmic rays, including atomic nuclei.

12 marks

Table 1 gives the data for one particular nucleus **X**.

Table 1

Mass / kg	8.02×10^{-26}
Specific charge / $C \text{ kg}^{-1}$	4.39×10^7
Kinetic energy / MeV	215

1

Determine the number of neutrons in nucleus **X**.

[3 marks]

number of neutrons =

2

Calculate the speed of **X**.
Ignore relativistic effects.

[3 marks]

speed = m s^{-1}

A pion (π^+) and a kaon (K^+) are produced when cosmic rays interact with the upper atmosphere.

3

The π^+ decays to produce a positron and an electron neutrino.

Show how the conservation laws apply to this decay.

[2 marks]

4

The K^+ decays to produce an anti-muon and a muon neutrino.

Explain how strangeness applies in this decay.

[2 marks]

5

Write an equation for a K^+ decay that involves only hadrons.

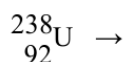
[2 marks]

17. Two stable isotopes of helium are ${}^4_2\text{He}$ and ${}^3_2\text{He}$. 12 marks

1 An atom of ${}^4_2\text{He}$ is produced in a rock that contains uranium. It is produced following the radioactive decay of a ${}^{238}_{92}\text{U}$ atom. The decay also creates an atom of thorium (Th).

Write an equation for the decay of ${}^{238}_{92}\text{U}$.

[2 marks]



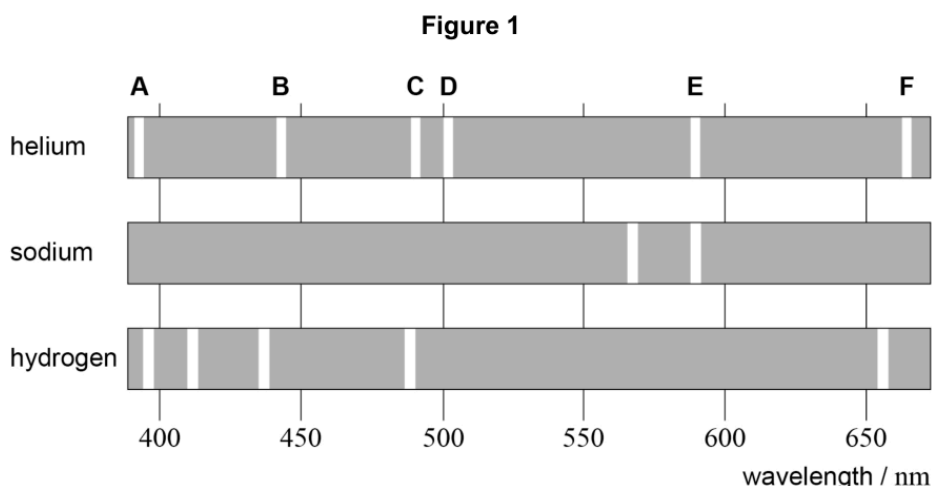
2 A ${}^3_2\text{He}$ nucleus can be produced by the decay of a tritium nucleus ${}^3_1\text{H}$.

State and explain which exchange particle is responsible for this decay.

[2 marks]

Helium was discovered by analysing the light in the **absorption** spectrum of the Sun.

Figure 1 shows the positions of the brightest lines, labelled **A** to **F**, in the **emission** spectrum of helium. The brightest lines in the emission spectra of sodium and hydrogen are also shown.



3 Before helium was identified, some scientists suggested that the lines of the helium spectrum seen in the absorption spectrum of the Sun were due to the presence of sodium and hydrogen.

Discuss, with reference to the lines **A** to **F** in **Figure 1**, the evidence for and against this suggestion.

[2 marks]

4 Calculate, in eV, the change in energy level responsible for the spectral line labelled **E** in **Figure 1**.

[3 marks]

change in energy level = eV

5

Explain, with reference to the processes within an atom, the difference between an emission spectrum and an absorption spectrum.

[3 marks]

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